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REPORT NO. T7/85

EFFECTS OF WEARING NBC PROTECTIVE CLOTHING IN THE HEAT ON DETECTION OF VISUAL SIGNALS

U S ARMY RESEARCH INSTITUTE
OF
ENVIRONMENTAL MEDICINE
Natick, Massachusetts

November 1985

UNITED STATES ARMY
MEDICAL RESEARCH & DEVELOPMENT COMMAND

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Sensitivity for detection of visual signals distributed at various locations throughout the visual field was studied in 16 male subjects during degrees of ambient heat exposure (91°F/61%RH; 70°F/35%RH; 55°F/35%RH), in combination with and without wearing of the Army NBC protective clothing system (MOPP-IV). Response time for signal detection increased systematically and significantly with peripheralization of stimulus locations, was most impaired in the superior and inferior visual field areas, and least affected along the horizontal axis

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area. The data support previous results obtained using this task. Both the heat and heat+MOPP-IV exposure conditions produced highly significant systematic increases in response time to all signals; the worst performance occurred under the heat+MOPP-IV combination. Implications for visual performance while wearing chemical protective gear are discussed.

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Effects of Wearing NBC Protective Clothing in the Heat
on Detection of Visual Signals

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FOREWORD

This study was conducted as part of the US Army Research Institute of Environmental Medicine in-house research program, and in conjunction with the mission objectives of the US Army Medical Research and Development Command Research Area III: Health Hazards of Military Systems and Combat Operations. The data were obtained in conjunction with another study to assess the effects of NBC protective clothing worn in the heat on performance of selected tasks typical of artillery fire direction center operations and other cognitively-based Army activities.

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ABSTRACT

Sensitivity for detection of visual signals distributed at various locations throughout the visual field was studied in 16 male subjects during degrees of ambient heat exposure (91°F/61%RH; 70°F/35%RH; 55°F/35%RH), in combination with and without wearing of the Army NBC protective clothing system (MOPP-IV). Response time for signal detection increased systematically and significantly with peripheralization of stimulus locations, was most impaired in the superior and inferior visual field areas, and least affected along the horizontal axis area. The data support previous results obtained using this task. Both the heat and heat+MOPP-IV exposure conditions produced highly significant systematic increases in response time to all signals; the worst performance occurred under the heat+MOPP-IV combination. Implications for visual performance while wearing chemical protective gear are discussed.

INTRODUCTION

Current military strategy for the modern battlefield involves the potential deployment of chemical and biological agents, as well as nuclear weaponry. In the face of such threats, the United States Army has developed equipment and clothing systems designed to protect personnel from exposure to nuclear, biological and chemical (NBC) hazards. This equipment, specifically the US Army Military Oriented Protective Posture (MOPP) system, is mandated for use by all US armed forces in operational situations involving a chemical hazard (Army Field Manual FM 21-40). This system is based on a concept of passive protection, and as such affords no external ventilation, heating or cooling to the wearer. It is intended to be used in a modular fashion, such that increasing degrees of encapsulation (designated MOPP-I, -II, -III, -IV) are available to achieve greater degrees of protection. At the highest level (MOPP-IV), the wearer is completely encapsulated, causing body moisture to become trapped inside the suit. This accumulated moisture quickly becomes a major problem for the wearer, both as a direct stressor and as an impediment to performance. The problem becomes even more critical when the MOPP system is worn in even moderately hot environments.

Some studies have investigated the physiological stress produced by the MOPP system on the wearer, particularly at the total encapsulation stage (MOPP-IV), both by itself and when the system is worn in the heat (Goldman & Breckenridge, 1976; Martin & Goldman, 1972). However, very little is known about effects which may be generated by this system both with and without heat exposure on psychological, cognitive and perceptual performance. Some of the available findings have indicated effects such as claustrophobia, incapacitation, and hallucinatory experiences by troops in field exercises (Brooks, et al, 1983; Newhouse, et al, 1981), although such reports have not been widespread. Nevertheless, the potential heat loads, discomfort levels and performance impairments to be anticipated when the MOPP-IV system is used in tropic or desert environments are currently a matter of serious concern to military planners and field commanders.

Other problems generated by the MOPP system, more of the human factors type, concern limitations of mobility, psychomotor and sensory-perceptual capability due to the encumbrances involved in providing total NBC protection. A particular concern in this area is interference with and restriction of functional vision, since the viewing ports of the protective mask limit the available visual field of the wearer. In hot environments, this problem is aggravated by trapped moisture condensing on the inside surface of the viewing ports, causing even further limitations to functional vision.

One aspect of visual activity directly related to many military operational tasks is the detection of events or signals of various kinds which are likely to occur anywhere in the field of view (e.g., as in sentry surveillance, aerial reconnaissance of ground targets, target detection and ranging by tank commanders, etc.). A laboratory task analog to the continuing process of visual field surveillance was developed at this Institute (Kobrick & Sutton, 1970), and in brief requires the subject to

monitor stimulus lights distributed about the visual field, which are activated intermittently and in a random pattern of locations. In previous research, this task has been found to sensitively reflect the effects of hypoxia (Kobrick, 1971, 1972, 1974, 1975; Kobrick & Appleton, 1971; Kobrick & Dusek, 1970), and in preliminary pilot tests at this Institute has also shown some impairment during heat exposure.

This paper reports the results of a study using the task cited above to assess the combined effects of wearing NBC protective clothing (MOPP-IV) during eight hours of exposure to hot-humid conditions on the ability to detect the occurrence of visual signals located throughout the visual field.

METHOD

Subjects

Twenty-four male soldier volunteers, ages 18 through 35, served as subjects. They were screened medically for any physical abnormalities which might be aggravated by heat exposure, for normal visual acuity (20/20 Snellen, corrected), normal visual fields and absence of scotomas. Prior to volunteering, they received a thorough briefing on the nature and purpose of the study, and were informed of all potential hazards involved. All subjects were then required to read and sign a volunteer agreement of informed consent before being allowed to participate.

Apparatus and Experimental Task

The performance data reported here were collected in conjunction with another study investigating the effects of heat and NBC clothing on performance of selected tasks used by artillery fire direction center (FDC) teams. A description of the FDC procedure is contained in Fine and Kobrick (1978).

The target detection task configuration consisted of a hemispheric array of 32 stimulus lights (3/16 in. round yellow light emitting diodes (LED's)) placed at a variety of locations throughout the subject's available field of view. The lights were arrayed along eight radial axes dispersed about the subject's central line of sight (see Figure 1). The axes were spaced at a standard angular separation of 45°, and each axis contained four lights displaced angularly from center (12°, 38°, 64°, 90°). The display was positioned so that the outermost (90°) ring of lights was located at the outer edge of the subject's peripheral visual field (approximately 90° eccentricity). The subject was instructed to view the display continuously while orienting to its center, and to depress a hand-held push-button switch whenever the onset of a signal light was detected.

The task used in the present study was a computerized modification of a previous manually controlled version (Kobrick and Sutton, 1970) which used white incandescent stimulus lights arrayed in essentially the same configuration. In the current version of the task employed in this study, the testing procedure was initiated and controlled by a Hewlett-Packard mini-computer (HP-87), which first instructed the subject via a voice synthesizer, and then administered the task. In each test run, the subject received all 32 stimulus lights presented in random order, with the provision that no light position was repeated. The time intervals between occurrences of stimuli

were also randomized between the limits of 5 and 25 seconds. Thus, the subject was never able to anticipate the time of onset or location of any stimulus. Undetected stimuli were considered to be missed after five seconds, and were given a response time score of that value, whereupon the next stimulus was presented. Upon completion of the test run, the system deposited the data in a file and printed out a graphic display of the averaged RTs as a function of the peripheral locations of the stimuli. A detailed account of this apparatus is reported elsewhere (Kobrick and Lussier, In press).

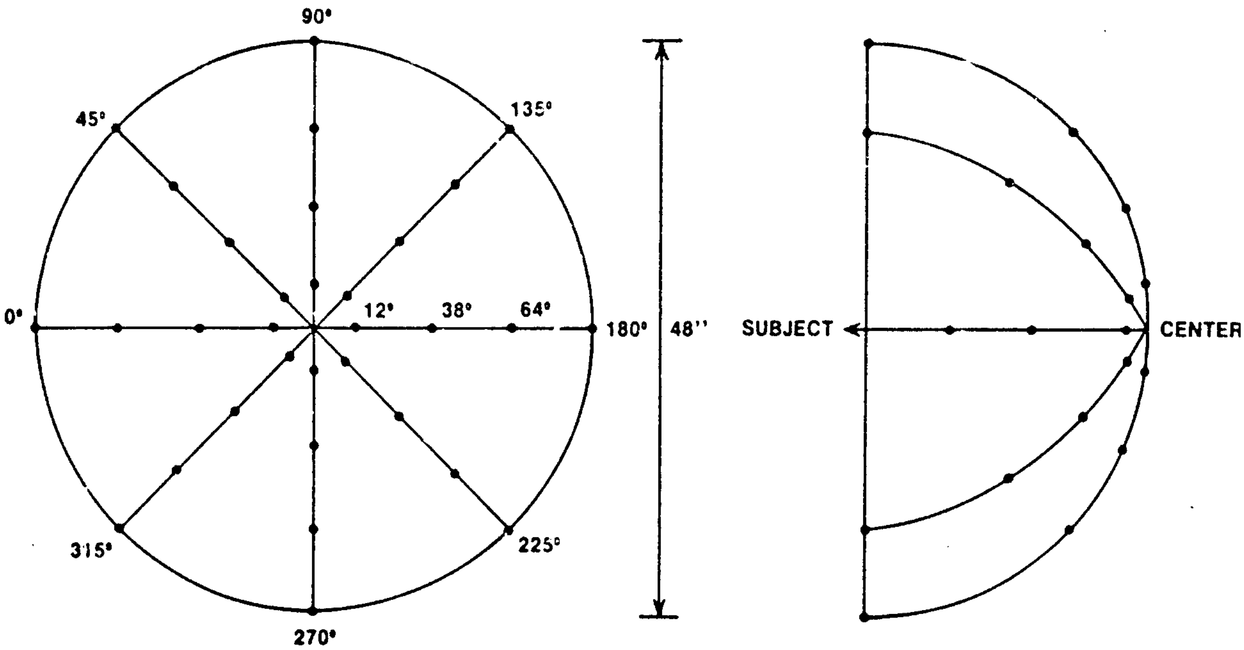

Figure 1. Schematic diagram of the stimulus presentation apparatus

Because of equipment and administrative constraints, the 24 subjects were tested in four separate replications (N = 6) of the total study. In each replication, the subjects were first instructed in correct performance of the various tasks involved in both collateral studies, followed by two weeks of daily training and practice on all tasks. This included one complete performance daily on the visual detection task involving one complete series of all stimulus lights, each light occurring once in the series.

During the following (third) week, the subjects performed the tasks in an environmental chamber while exposed to the following daily sequence of experimental treatment conditions: Day 1: 70° F./35% RH - 2-hour refresher and rehearsal of all experimental tasks, while wearing comfortable civilian attire; Day 2: 70° F./35% RH - first baseline control condition, while wearing Army battledress uniform; Day 3: 55° F./35% RH - experimental test condition, while wearing totally encapsulating NBC protective ensemble (MOPP-IV); Day 4: 70° F./35% RH - second baseline control condition, while wearing Army battledress uniform; Day 5: 91° F./61% RH - experimental test condition, while wearing totally encapsulating NBC protective ensemble (MOPP-IV). On each test day, the subjects performed the tasks repeatedly over a continuous eight-hour period of exposure to the respective test conditions. This included a complete performance of the visual field task at the end of the first, third and fifth hours of exposure.

RESULTS AND DISCUSSION

Eight of the 24 subjects failed to complete the entire study because of administrative and medical problems which developed during the course of exposure to the experimental conditions. Therefore, analysis of the results is based on the performance of the remaining 16 subjects who did complete all conditions. The basic data used for analysis were the response times (RTs) in millisecond units intervening between the onset of each stimulus light and the closure of the subject's switch. Missed signals were arbitrarily assigned a value of five seconds.

Individual arithmetic means were first calculated for each subject for each set of eight lights displaced at 12°, 38°, 64° and 90° from center (rings); and for each set of four lights distributed angularly at 0°, 45°, 90°, 135°, 180°, 225°, 270° and 315° inclination about the center of the display (axes). (See Figure 1.) The means for rings are intended to reflect the effect of peripheralization of the stimulus, and the means for axis are meant to indicate the effect of general location of stimuli in the overall visual field. These two sets of subject means were obtained for each of the three hourly tests conducted under each of the four daily experimental test conditions, and form the data base upon which the results of the study were analyzed. The group mean response times for the various experimental conditions are summarized in the Appendix. A separate three-way multivariate analysis of variance for repeated measures was then performed for the ring data (rings (R) x test day (D) x hourly sequence (H)); and for the axis data (axis (A) x test day (D) x hourly sequence (H)). These analyses were conducted by means of the Biomedical Data Package (BMDP) Program P4V (University of California Press, 1981).

The results of these analyses indicated highly significant main effects for peripheral location of the stimulus rings (R) ($F=89.65$; $df=3,45$; $P=<.00001$); and for relative location of the stimulus axes in the visual field (A) ($F=9.68$; $df=7,105$; $P=<.00001$). Highly significant main effects were also obtained for the daily sequence of experimental test conditions (D); both for rings ($F=29.83$; $df=3,45$; $P=<.00001$, and for axes ($F=31.56$; $df=3,45$; $P=<.00001$). The first-order interactions of daily testing conditions with rings, and of daily testing conditions with axes were also highly significant (D x R: $F=2.16$; $df=9,135$; $P<.02$); (D x A: $F=3.40$; $df=21,315$; $P<.00001$). The main effects of hourly sequence of testing within days did not reach significance. However, the first-order interaction of test day with hourly testing sequence for rings was significant (D x H: $F=2.43$; $df=6,90$; $P<.03$); the same interaction for axis was not. Thus, the results indicate significant alterations in overall response time for signal detection due both to peripheral displacement of the stimulus, and to its relative location in the visual field. The present results also indicate major alterations of signal detection capability due to wearing of the MOPP-IV system, both under comfortable temperature conditions and during heat exposure.

It would seem, however, that there was no progressive cumulative effect of wearing the MOPP system over the daily eight-hour testing session either with or without heat exposure. An inspection of the individual subject performance curves (not shown for brevity) indicated that on the whole the impairments occurred early during the test sessions, and remained at that level for the rest of the day. This indicates that the actual effects of the MOPP configuration on the functional field of vision are significant and seri ·us, whether or not heat exposure is involved. Furthermore, these eff· ts can be expected to have a major influence on the performance capability of the wearer throughout the total period of use. The subsequent course of visual field impairment beyond eight hours is another matter for serious consideration, even though the MOPP system is not intended for use beyond 6-8 hours in typical situations. However, the nature of such longer-term effects cannot be determined on the basis of this study.

In order to assess the distribution of impairment to performance produced by the experimental conditions for the various stimulus locations throughout the visual field, the overall daily group mean RTs were calculated for each peripheral ring of stimuli (12°, 38°, 64°, 90°) for each daily experimental condition. These values are shown graphically in Figure 2, in which the group mean RTs are represented as a function of peripheral rings, and each experimental condition is represented by a separate curve.

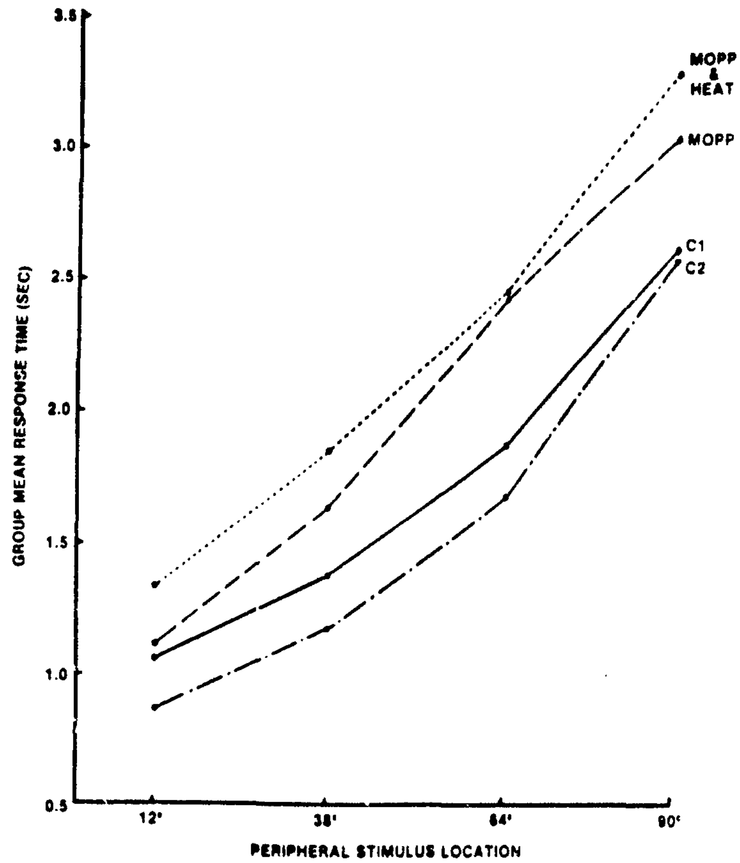

Figure 2. Group mean response times (SEC) as a function of peripheral location of stimuli

It can be seen in Figure 2 that the mean RTs increased systematically with greater peripheralization of the stimuli within all four experimental conditions, and that the impairments became substantially greater under both the MOPP and MOPP+heat conditions, with no inversions among the curves. This general configuration of the data is consonant with the findings of previous research using this task (Kobrick, 1971, 1972, 1974, 1975; Kobrick & Appleton, 1971; Kobrick & Dusek, 1970). Also, it appears that the MOPP+heat condition had a moderately greater influence on RT performance than did the MOPP condition alone. It should further be noted in this representation of the data that some improvement in performance seems to have occurred from the first to second control condition, suggesting that a somewhat longer practice and training period may be necessary in future use of this task.

The overall daily group mean RTs for the four stimuli on each of the eight axes (0^{o}, 45^{o}, 90^{o}, 135^{o}, 180^{o}, 225^{o}, 270^{o}, 315^{o}) were also calculated. These values are shown graphically in Figure 3, in which the group mean RTs

are shown as a function of axes, and each experimental condition is again represented by a separate curve.

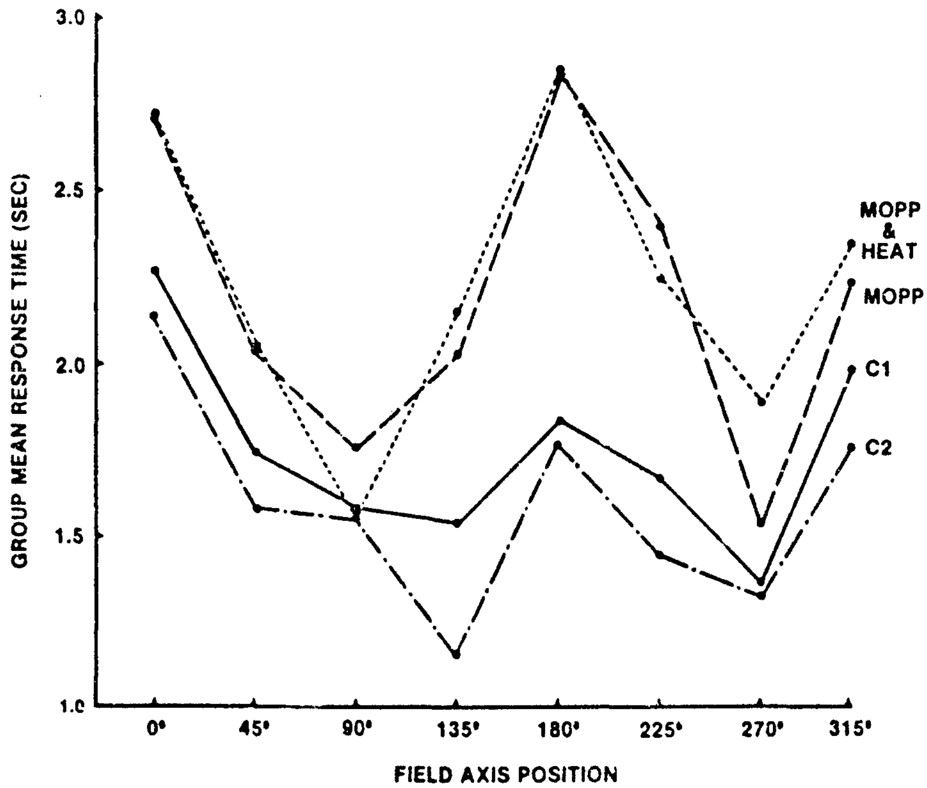

Figure 3. Group mean response times (SEC) as a function of axial position of stimuli

It can be seen in Figure 3 that the mean RTs increased systematically with stimulus locations in the superior and inferior visual field areas, with the least impairment occurring along the horizontal axis of view. This response configuration is consistent with the findings of previous research using this task, and indicates that normal viewing is most effective along the conventional horizon line of sight, where most visual activity normally takes place. The impairments in this representation were substantially greater in the MOPP and MOPP+heat conditions, and it would appear again that the MOPP+heat condition had a slightly more severe effect than did the MOPP condition alone. There is again an indication of improvement in performance from Control 1 to Control 2.

In order to identify the overall changes in performance which occurred due to the main experimental conditions (MOPP-IV and heat exposure), the overall group arithmetic means were calculated for the entire data for each day of testing. These values are shown graphically in Figure 4, in which the daily grand means are represented as a function of the daily testing conditions.

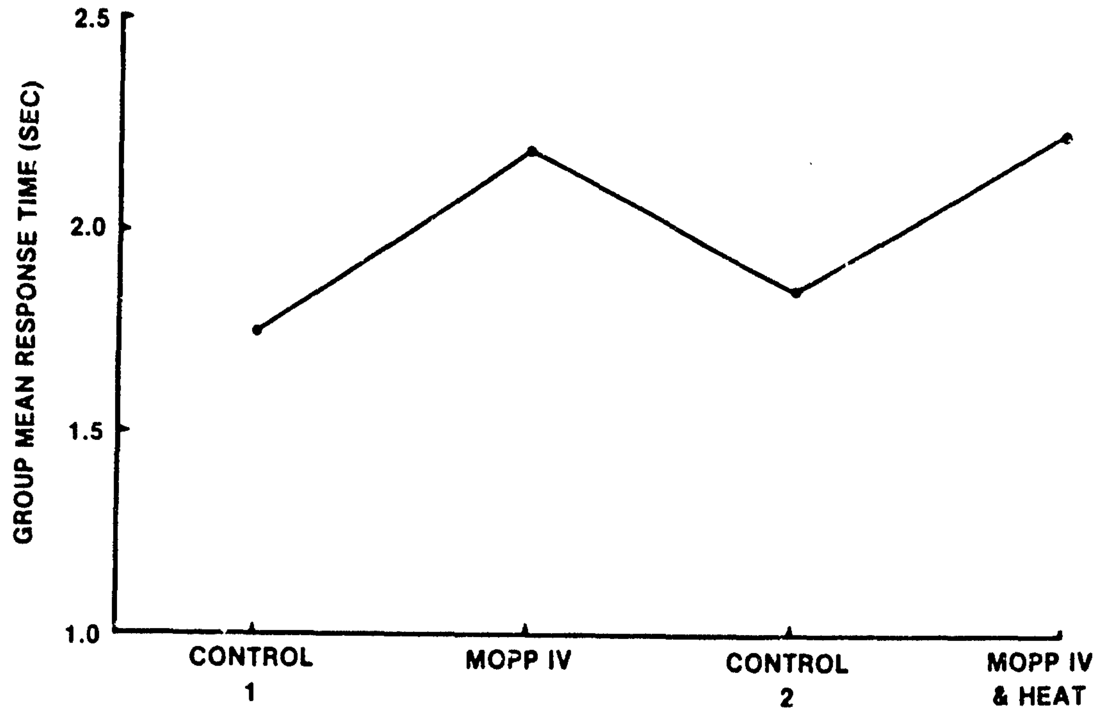

Figure 4. Overall group mean response times (SEC) for each daily experimental test condition

It can be seen in Figure 4 that, in comparison to control performance, the MOPP-IV condition apparently resulted in a substantial change in response time over the visual field in general. Furthermore, this change occurred to about an equal degree both with and without heat exposure, Thus, the MOPP-IV system clearly imposed a significant encumbrance to performance of this type of visual task despite the environmental conditions, and should be noted as a significant matter for consideration in future re-design of the protective mask.

With regard to the control conditions, no appreciable difference is evident between Controls 1 and 2 on the basis of the overall group averages of all data for each experimental condition. Despite this, differences were noted between Controls 1 and 2 for the group averages calculated for rings (Figure 2), and for the group averages for axes (Figure 3). These latter differences, however, would only serve to bolster the significance of the subsequent impairment under the MOPP-IV+heat condition, since the ensuing impairment could only have been reduced by the continuing improvement in RT due to practice.

Finally, it should be pointed out that the impairments of RT observed in this study (1 to 2 seconds, on the average) are of practical significance, since such values in the reaction time literature would be considered to be quite large.

CONCLUSIONS

The visual detection sensitivity task used in this study has shown that RT for signal detection increased in direct relation to the peripheral location of the stimulus, and that best performance occurred for stimuli nearest the horizontal axis of view. Response times became progressively impaired for stimulus locations toward the superior and inferior axes of the visual field. These results confirm the findings of previous studies in which this task was employed. Wearing of the MOPP-IV NBC system with protective mask was shown to result in further impairment of this overall response configuration, both during and without heat exposure, to different degrees but in approximately the same fashion. These results indicate a serious limitation to functional vision by the MOPP-IV system, which occurs early and evidently remains undiminished as long as the system is worn. Considering the general importance of visual field capability, particularly in critical tasks such as pilot, gunner and tank commander, these results are felt to point up a serious issue for operational effectiveness in situations requiring the use of chemical protective clothing.

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APPENDIX OF TABLES

TABLE I

GROUP MEAN RESPONSE TIMES (SEC) BY TEST CONDITIONS
BY HOURS OF EXPOSURE BY PERIPHERAL RINGS

HOUR	RINGS 12°	38°	64°	90°
Control 1				
1	1.075	1.463	2.002	2.476
3	1.027	1.244	1.950	2.554
5	1.138	1.481	1.731	2.813
MOPP-IV				
1	1.052	1.500	2.074	2.665
3	1.215	1.646	2.614	3.244
5	1.078	1.707	2.555	3.335
Control 2				
1	0.901	1.111	1.756	2.549
3	0.781	1.291	1.772	2.695
5	0.913	1.177	1.553	2.542
MOPP-IV + HEAT				
1	1.205	1.690	2.463	3.268
3	1.197	1.760	2.322	3.070
5	1.579	2.037	2.583	3.491

TABLE II

GROUP MEAN RESPONSE TIMES (SEC) BY TEST CONDITIONS
BY HOURS OF EXPOSURE BY FIELD AXES

HOUR	AXIS 0°	45°	90°	135°	180°	225°	270°	315°
Control 1								
1	2.394	1.903	1.543	1.541	2.065	1.620	1.201	1.766
3	2.149	1.708	1.720	1.478	1.539	1.547	1.398	2.012
5	2.325	1.593	1.448	1.624	1.863	1.822	1.488	2.164
MOPP-IV								
1	2.625	2.092	1.990	2.115	2.691	2.303	1.529	2.315
3	2.722	1.962	1.788	2.028	2.870	2.542	1.438	2.089
5	2.755	2.062	1.508	2.036	2.863	2.331	1.568	2.227
Control 2								
1	2.071	1.646	1.515	1.222	1.841	1.240	1.276	1.827
3	2.094	1.619	1.539	1.189	1.894	1.487	1.432	1.826
5	2.191	1.470	1.559	1.105	1.579	1.598	1.228	1.639

TABLE II (CONT'D.)

MOPP-IV + HEAT								
1	2.633	1.800	1.422	2.142	2.825	2.112	2.092	2.224
3	2.680	2.141	1.503	1.909	2.588	2.133	1.681	2.064
5	2.824	2.269	1.707	2.450	3.036	2.464	1.876	2.754

TABLE III

OVERALL GROUP MEAN RESPONSE TIMES (SEC)
FOR THE EXPERIMENTAL TEST CONDITIONS

RESPONSE / TIME (MSEC)/	CONTROL I	MOPP-IV	CONTROL II	HEAT+MOPP-IV
	1.746	2.185	1.587	2.222

	HOUR 1	HOUR 3	HOUR 5
	1.828	1.899	1.982

	12° RING	38° RING	64°RING	90° RING
	1.097	1.509	2.115	2.892

AXIS

0°	45°	90°	135°	180°	225°	270°	315°
2.455	1.855	1.603	1.736	2.305	1.933	1.517	2.076

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